www.sospublication.co.in Journal of Advanced Laboratory Research in Biology

We- together to save yourself society e-ISSN 0976-7614

Volume 1, Issue 2, October 2010 Original Article

Assessment of Heavy Metal Contamination in the Sediments of a River Draining into a Ramsar Site in the Indian Subcontinent

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Abstract: Concentrations of six heavy metals (Cd, Cr, Ni, Zn, Pb and Cu) in surface sediments of Achankovil river basin which is draining into a Ramsar site in India viz. The Vembanad wetland system was determined. To assess metal concentrations in sediment, numeric Sediment Quality Guidelines (SQGs) were employed. The concentrations of Zn, Cr and Pb in all sediment samples are lower than the proposed threshold effect concentrations which indicate that there are no harmful effects from these metals. On the other hand, the concentrations of Cd in one station, Cu in three stations and Ni in all stations exceeded the threshold effect concentrations indicated that these stations were in potential risk. The metal contamination in sediments was evaluated by applying Index geoaccumulation, metal pollution index, Enrichment factor and Multivariate statistical techniques. The low values of EF show that the enrichment of sediment by heavy metal was by natural processes.

Keywords: Heavy Metal, Surface River Sediment, Geoaccumulation Index, Metal Pollution Index, Contamination Factor, Enrichment Factor, Principal Component Analysis.

1. Introduction

Metals are natural constituents in nature. In fact, during the last few decades, industrial and urban activities have contributed to the increase of metals contamination. The pollution of heavy metals is an important cause of soil destruction. The danger of heavy metals, unlike other pollutants, lies in their being nondegradable and the accumulation in the earth's surface. By food chain heavy metals in the soil may pile up in the body of human as well as livestock, endangering human health directly or indirectly.

Heavy metal pollution of aquatic ecosystems is becoming a potential global problem. Trace amounts of heavy metals are always present in fresh waters from terrigenous sources such as weathering of rocks resulting into a geochemical recycling of heavy metal elements in these ecosystems [25 & 42]. Trace elements may be immobilized within the stream sediments and thus could be involved in the absorption, co-precipitation and complex formation [22 & 29]. Sometimes they are co-adsorbed with other elements as oxides, hydroxides of Fe and Mn or may occur in particulate form [1 & 26]. Heavy metals may enter into aquatic ecosystems from anthropogenic sources, such as industrial wastewater discharges, sewage wastewater, fossil fuel combustion and atmospheric deposition [3, 8, 15, 17 & 20]. Trace elemental concentrations in stream sediment compartments can be used to reveal the history and intensity of local and regional pollution [27].

Sediments act as sinks and sources of contaminants in aquatic systems because of their variable physical and chemical properties [9, 30 & 32]. Analysis of pollutants in sediments is vital as they were adsorbed by material in suspension and by fine-grained particles [32]. Pekey (2006) [30] demonstrated that the heavy metals tend to be trapped in aquatic environments and accumulate in sediments. According to Caeiro *et al.*, (2005) [2], the concentration of metal contaminants can be classified into three types which are:

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i. Contamination indices which compare the contaminants with the clean or polluted stations measured elsewhere.
ii. Background enrichments indices-which compare the results for the contaminants with the baseline or background levels and
iii. Ecological risk indices- which compare the results for the contaminants with Sediment Quality Guidelines (SQG).

Environmental quality indices are a powerful tool for development, evaluation and conveying raw environmental information to decision makers, managers, technicians or for the public. Sediment quality values are useful to screen the potential for contaminants within the sediment to induce biological effects and compare sediment contaminant concentration with the corresponding quality guideline [36]. These indices evaluate the degree to which the sediment-associated chemical status might adversely affect aquatic organisms and are designed to assist sediment assessors and managers responsible for the interpretation of sediment quality [2]. It is also to rank and prioritizes the contaminated areas or the chemicals for the further investigation [10].

The aim of this study is to assess the level of metal concentrations in surface sediments in the Achankovil river which is a major river draining into a Ramsar Wetland Viz. Vembanad-Kol wetland system in India, examining the occurrence and distribution of metals and to explore the natural and anthropogenic input of heavy metals and to assess the pollution status on the area and to highlight the relationships among metals.

2. Research Methodologies and Methods

2.1 Study area

The river Achankovil is the ninth largest river in terms of catchment area and sixth in terms of length among the 41 west flowing rivers of the State of Kerala, ($8^{0}17'$ 30" and $12^{0}47'$ 40" N latitude and $74^{0}24'$ 47" E longitude) a southern state in the Indian subcontinent. The river discharges into the Vembanad wetland system which is a Ramsar wetland in the Indian subcontinent. The river has its origin from two hill ranges of Western ghats Viz, Devermalai in the Pathanamthitta District at an elevation of 700 meters above Mean sea level and Kottavasal in the Kollam District at an elevation of 1,000 meters above mean sea level. The Achankovil river basin lies between latitudes $9^{0}01$" to $1^{0}00$" North and longitudes $76^{0}23$" to $77^{0}16$" East (Fig. 1). The river basin extends over a land strip of 1484 square kilometers with a total length of about 128 kilometers across the state of Kerala, between the Western Ghats and Arabian Sea, lying parallel to the Kallada river basin in the south and a Parnba river basin in the north. The soils of the basin are grouped as, laterite, forest loams, river alluvium, brown hydromorphic and grayish onattukara.

2.2 Sediment sampling and chemical analysis

Samples were taken in premonsoon season (April 2010) from seven stations of Achankovil River (Fig. 1). Station code; latitude and longitude of stations are given in Table 1.

Table 1: Location and sampling code of sediment samples.

Sampling code	Sampling station	Latitude	Longitude
AK1	Thuruthelkadavu	9^{0}19’28.1”	76^{0}29’51.7”
AK2	Kupparakadavu	9^{0}19’13.1”	76^{0}29’ 6.5”
AK3	Mavelikkara	9^{0}15’26.7”	76^{0}32’25.6”
AK4	Kolanada	9^{0} 14’ 4.2”	76^{0}14’ 22.2”
AK5	Pramadam	9^{0}15’ 6.7”	76^{0}49’ 1.4”
AK6	Aruvapulamkadavu	9^{0}12’ 43.8”	76^{0}52’22.8”
AK7	Kakkathode	9^{0}15’ 6.6”	76^{0} 49’ 1.4”

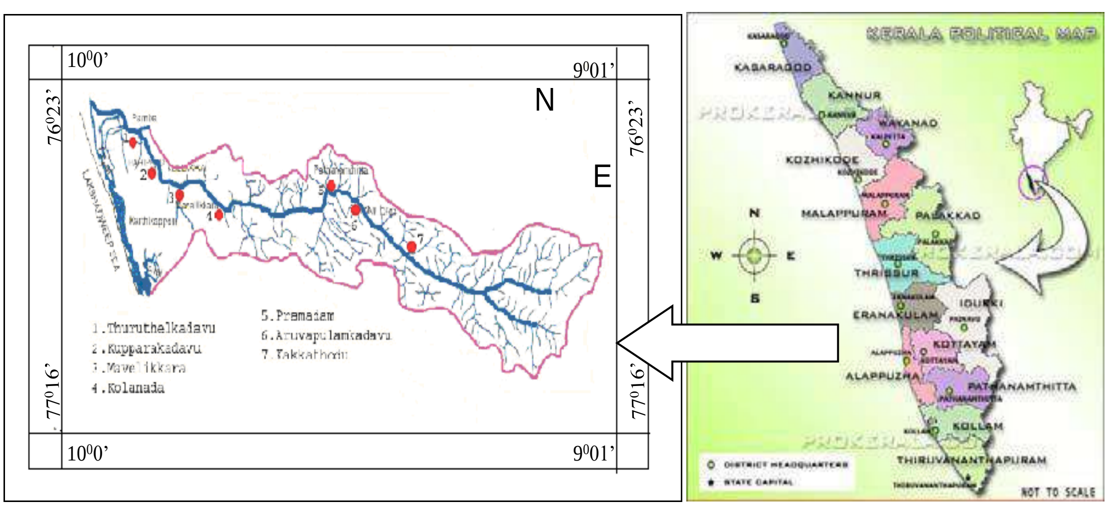

Fig. 1. Map showing sediment sampling locations.

Surface sediment samples were taken at a depth of 10cm which was quickly packed in air tight polythene bags. Subsamples of the material were oven dried at 45^0C for 48 hours and ground using mortar and pestle. Then the samples were sieved by a sieve (aperture 125µm). The lower particle size fraction was homogenized by grinding again in the mortar and stored in plastic bottles until chemical analyses were carried out and marked well. Precautions were taken to avoid contamination during drying, grinding, sieving and storage. For the determination of trace metals (Cu, Mn, Ni, Cr, Pb & Zn) the acid extraction were carried out and trace metal concentration [16] was determined by AAS (Varian Spectra AA10). All the reagents and chemicals used were of analytical grade.

2.3 Assessment of Metal Contamination

a) Contamination Factor and Degree of Contamination

The contamination factor C_f and the degree of contamination were used to determine the contamination status of the sediment in the present study. C_f values are suggested for describing the contamination factor [13]. $C_f < 1$: low contamination factor; $1 \leq C_f < 3$: moderate contamination factor; $3 = C_f < 6$: considerable contamination factor; $C_f = 6$: very high contamination factor.

The degree of contamination (C_d) was defined as the sum of all contamination factors. The following terminology was adopted to describe the degree of contamination (C_d values) for the selected six metals. $C_d < 6$: low degree of contamination; $6 = C_d < 12$: moderate degree of contamination; $12 = C_d < 24$: considerable degree of contamination; $C_d = 24$: very high degree of contamination indicating serious anthropogenic pollution.

b) Background Enrichments Indices (Indices calculation)

i. Geoaccumulation index: To understand the current environmental status and the metal contamination with respect to natural environmental, other approaches should be applied. A common criterion to evaluate the heavy metal pollution in sediments is the geoaccumulation index (*I*geo), which was originally defined by Muller (1979) to determine metals contamination in sediments, by comparing current concentrations with pre-industrial levels and can be calculated by the following equation [13]:

$$\boldsymbol{I\text{geo} = \log_2 [C_n / (1.5 * B_n)}$$

Where *n* is the measured concentration of the examined metal (*n*) in the sediment, Bn is the geochemical background concentration of the metal (*n*) and factor 1.5 is the background matrix correction factor due to lithogenic effects. Muller (1981) has distinguished seven classes of geoaccumulation index (Table 2) [14].

Table 2. Muller's classification for the Geoaccumulation index (1981).

*I*geo value	Class	Quality of sediment
<0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly to extremely polluted
≥6	6	Extremely polluted

ii. Metal Pollution Index: In order to evaluate the overall degree of stream sediment metal contamination, the Metal Pollution Index (MPI) was calculated according to Goncalves *et al*., (1994) [12] MPI is defined as the linear sum of the contamination factors weighed to take into account the differences in toxicity of the various metals:

$$\mathbf{MPI} = \sum_I (W_i / Wt) * CF_i$$

Where CF_i is the contamination factor of metal *I*, *Wi* is the weight of metal *I* and $Wt=\sum_i Wi$ The weights of metals Zn, Cu, Cr, Pb, Ni and Cd were established by Gonçalves *et al*., [12].

c) The enrichment factor

The enrichment factor is the relative abundance of a chemical element in a soil compared to the bedrock [14]. Enrichment factor is a convenient measure of geochemical trends and is used for comparison between areas.

Enrichment factor = (Cn/Fe) sample/ (Cn/Fe) background

Where Cn is the concentration of element "n". The background value is that of average shale [40]. An element qualifies as a reference one if it is of low occurrence variability and is present in the environment in trace amounts [19]. An element which is naturally derived has an EF value of nearly unity, while elements of anthropogenic origin have EF values of several orders of magnitude. Six categories are recognized [37]:

< 1 Background concentration,
1-2 Depletion to minimal enrichment,
2-5 Moderate enrichment,
5-20 Significant enrichment,
20-40 Very high enrichment and
>40 Extremely high enrichment.

As the Enrichment factor increase, the contributions of the anthropogenic origins also increase [37].

2.4 Ecological evaluation of heavy metals

The ecological risk assessment of sediment is the core of quality management, of which heavy metal is the focus [14]. Ecological risk assessment is the establishment of the necessary conditions for SQC sediment quality criteria [41]. The Environmental Management Information System is a vital component and expertise system, with planning, guidance and early warning function. Liu and others made a new multi-utilization evaluation system [40] with ecological indicators for the potential pollution of heavy metals in river sediment risk assessment program [18 & 38].

According, to the feature of heavy metal nature and the environment, Swedish scholars put forward potential ecological risk index method from the angle of sedimentology [13] to assess heavy metal of soil (sediment). This method, as one of advanced international methods to research on the heavy metals in soils (sediments), reflects not only the influence of pollutants in a particular environment but also the comprehensive effects and the quantitative methods carved up potential ecological risk levels. Because of the differences in the toxicity of different heavy metals and environmental sensitivity of heavy metals, the potential impact of heavy metals on the environment can be accurately indicated. The Potential Ecological Risk Index is obtained with a relatively fast, simple and standard method from a certain number of the sediment samples. In the studies of the impact assessment of heavy metals in the environment, the potential ecological risk index is applied [6, 18 & 38]. Potential ecological harm index takes four basic conditions as the principle:

1) Content is condition is to compare the measurements of heavy metals in surface sediments with a series of natural background values of each pollutant.
2) Number condition is based on the view that selecting a certain number of samples can meet the actual needs. The selected experimental samples from sediment samples include the changing value of all the content. In fact, the selected pollutants (Cu, Cd, Pb, Zn and Cr) and their content coefficients represent the standard harm degree.
3) Toxic condition is based on the principle of abundance to distinguish various pollutants. The deposition of solid metal and toxic substances make a proportional relationship between toxicity and scarcity. After a series of standardized treatment, sedimentary toxicity coefficients are in the following order:

$$Zn = 1 < Cr = 2 < Cu = Pb = 5 < Cd = 30$$

4) The sensitivity condition means that different regions are sensitive to different toxic substances. Various parameters of this study and the concentration of heavy metals in surface sediments are based on the measurements of the investigation. The potential ecological risk index method is widely applied to the assessment of the ecological risk of heavy metals in the environment [34]. The potential ecological risk of a given contaminant according to Hakson's (1980) [34] is;

$$\mathbf{E^i_f = T^i_f .\ C^i_f .}$$

T^i_f is the toxic response factor for a given substance; C^i_f is the contamination factor. The sum of the individual potential risks is the potential risk of the water body. In keeping Hakson (1980) [34], the following terminology is used for RI values. RI values < 50 represents low ecological risk, while RI > 600 is an indicator of very high ecological risk of the water body.

2.5 Multivariate data analysis techniques

SYSTAT software was employed to determine whether groups of variables have the same means of data that are continuous or normally distributed and with homogeneous variance. Additionally, it was employed to assess the relationship between heavy metal concentrations and their elemental relationship between sections of the stream. Correlation analysis: Pearson correlation analysis was adopted to analyze and establish inter-metal relationship of heavy metals of river sediments. PCA carried out on a correlation matrix substitutes the original variables with a smaller number of new variables, which reduces the dimensionality of the problem and enables an interpretation of the relationships among variables and sampling sites. By extracting the eigenvalues and eigenvectors of the correlation matrix, we identified the number of significant factors, the percentage of variance explained by each of them, and the participation of the old variables in the new ones [31]. Factor analysis was employed on the variables that are correlated to isolate or determine the specific factors that are associated with such groupings of metal concentration. This type of factor analysis has been widely used to identify the sources of pollution [35].

3. Results and Discussion

3.1 Comparative study of sediment samples of Achankovil river sediments with geochemical background and toxicological reference value

Cadmium concentration of samples ranged from 0.52mg/kg to 1.10mg/kg, Pb concentration varied from 3.95mg/kg to 25.36mg/kg, Ni varied from 33.20mg/kg to 45.6mg/kg, Zn varied from 22.50mg/kg to 97.50mg/kg, Cr varied from 12.5mg/kg to 23.6mg/kg and Cu varied from 0.30mg/kg to 69.23mg/kg. Cadmium concentrations of all samples were above shale standard. Comparison of sediment heavy metal concentration with shale standard is shown in Table 3.

The accumulation of heavy metals in sediments can be a secondary source of water pollution, once an environmental condition is changed [6 & 7]. Therefore, an assessment of heavy metal contamination in sediments is an indispensable tool to assess the risk of an aquatic environment. To assess metal concentrations in sediment, Numerical Sediment Quality Guidelines (SQGs) were applied. SQGs include a threshold effect concentration (TEC) and a probable effect concentration (PEC) (Table 3). If the metals in sediments are below the TEC, harmful effects are unlikely to be observed. If the metals are above the PEC, harmful effects are likely to be observed Mac Donald *et al.*, [6]; noted in his studies that most of the TECs provide an accurate basis for predicting the absence of sediment toxicity and most of the PECs provide an accurate basis for predicting sediment toxicity [21]. The concentrations of Zn, Cr and Pb in all sediment samples are lower than the proposed TECs indicated that there are no harmful effects of these metals. On the other hand, the concentrations of Cd exceeded TEC in station 3, Cu in stations 5, 6 & 7 and Ni in all stations exceeded the TEC indicated that these stations were in potential risk.

3.2 Sediment quality guideline as per United States Environmental Protection Agency (USEPA)

The chemical contamination in the sediments was evaluated by comparing with the sediment quality guideline proposed by USEPA. These criteria are shown in Table 4.

Mn, Cd, Cr and Pb in all stations under investigation belong to unpolluted sediments, while station 6 is considered as moderately polluted by Cu while the stations 5 & 7 belong to heavily polluted. On the other hand, Cd, Cu and Ni in all studied sediments belong to moderately polluted sediments. Ni in all stations is moderately polluted.

Table 3. Trace metal concentration of heavy metals (in mg/kg) sediment samples collected from an Achankovil river basin.

Station No	Cd	Pb	Ni	Zn	Cr	Cu
1	0.99	7.75	43.29	62.10	21.6	7.24
2	0.89	8.85	40.50	31.25	18.12	4.82
3	1.10	10.25	45.60	97.50	23.65	5.23
4	0.98	8.55	41.60	22.50	18.60	0.30
5	0.80	3.95	38.56	96.78	14.90	54.86
6	0.86	25.36	39.80	53.45	16.12	34.56
7	0.52	10.15	33.29	72.55	12.5	69.23
Maximum	1.10	25.36	45.60	97.50	23.65	69.23
Minimum	0.52	3.95	33.20	22.50	12.50	0.30
Arithmetic mean	0.80	10.69	40.37	62.30	17.92	25.17
Standard deviation	0.18	6.80	3.84	29.30	3.84	27.86
Shale standard	0.30	20.0	68.0	95.00	90.0	45.0
TEC	0.99	35.80	22.70	121.0	43.40	31.60
PEC	4.98	128.0	48.6	459.0	111.0	149.0

Table 4. EPA guidelines for sediments.

Metal	Not polluted	Moderately polluted	Heavily polluted	Present study
Cd	-	-	>6	0.52-1.1
Cr	<25	25-75	>75	12.5-23.6
Cu	<25	25-50	>50	0.30-69.23
Ni	<20	20-50	>50	33.29-45.6
Pb	<40	40-60	>60	3.95-25.36

Table 5. Geoaccumulation index (*I*geo values) of heavy metals in sediments from Achankovil River.

Stations	*I*geo values					
	Cu	Ni	Cd	Pb	Zn	Cr
1	-3.22	-1.23	1.13	-1.95	-1.19	-2.64
2	-3.80	-1.33	0.98	-1.76	-2.18	-2.89
3	-3.69	-1.16	1.28	-1.54	-0.54	-2.51
4	-7.78	-1.29	1.12	-1.81	-2.66	-2.85
5	-0.29	-1.40	0.83	-2.92	-0.55	-3.17
6	-0.96	-1.35	0.93	-0.24	-1.41	-3.06
7	0.03	-1.61	0.20	-1.56	-0.97	-3.43

3.3 Assessment According to Geoaccumulation Index

According to, Geoaccumulation index all stations are unpolluted for Cu, Ni, Pb and Cr. Stations 2, 5, 6 and 7 are unpolluted to moderately polluted and stations 3 and 4 are moderately polluted with Cd. *I*geo values of heavy metals in sediments are shown in Table 5.

The variation of Geoaccumulation index of the sediment samples was shown in Fig. 2.

3.4 Assessment according to Contamination Factor and Degree of Contamination

Maximum value of contamination factor for cadmium was noticed for sediment off at station 3 while the minimum C_f was recorded at station 7 (Table 6). Station 1, 3 and 4 had considerable contamination factor values for cadmium according to the Hakanson's classification, while the rest of the investigated stations recorded a moderate contamination for this metal. All stations in the present study recorded low contamination factor for Cr and Ni. Zn and Cu exhibited moderate contamination for stations 7 and station 5. Moderate contamination for Pb was recorded for Station 6. Station 3 recorded the maximum value of the degree of contamination while station 2 recorded the lowest degree of contamination as illustrated in Table 6. Stations 3 and 6 recorded moderate degree of contamination while the rest of stations revealed a low degree of contamination.

3.5 Assessment according to Metal Pollution Index

Metal Pollution Index (MPI) for the investigated stations is illustrated in Table 6. Stations 5 and 7 can be classified as low contamination areas where MPI < 2, while other stations had MPI values > 2 confirming there were considerable contamination for the previous six metals according to the classification of Gonçalves *et al*., (1994) [12]. Variation of Metal Pollution Index of sampling stations was shown in Fig. 3.

Table 6. Contamination factor, the degree of contamination and MPI of sediment samples collected from Achankovil River.

Stations	C_f values						C_d	MPI
	Cu	Ni	Cd	Pb	Zn	Cr		
1	0.160	0.636	3.300	0.387	0.653	0.240	5.378	2.321
2	0.107	0.595	2.966	0.442	0.328	0.201	4.642	2.376
3	0.116	0.670	3.666	0.512	1.026	0.262	6.255	2.569
4	0.006	0.611	3.2665	0.427	0.236	0.206	4.756	2.277
5	1.219	0.567	2.666	0.197	1.018	0.165	5.834	0.352
6	0.768	0.585	2.866	1.268	0.562	0.179	6.229	2.097
7	1.538	0.489	1.7333	0.507	0.763	0.138	5.171	1.392

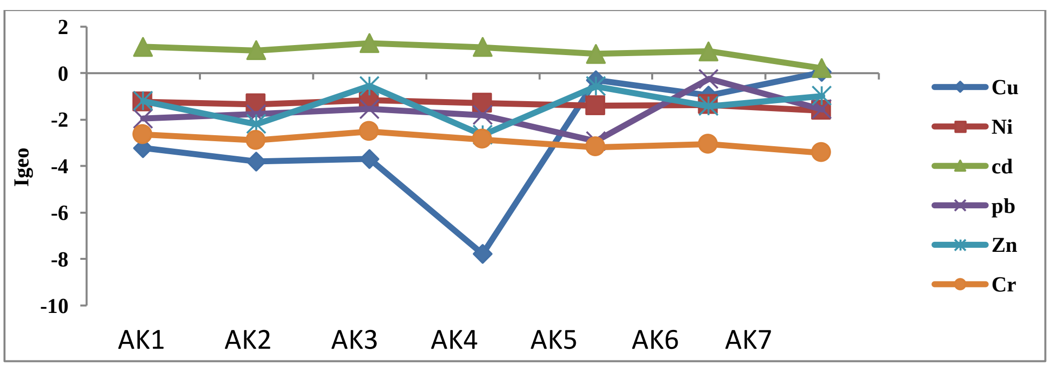

Fig. 2. Variation of *I*geo values of heavy metals in sediments from Achankovil river basin.

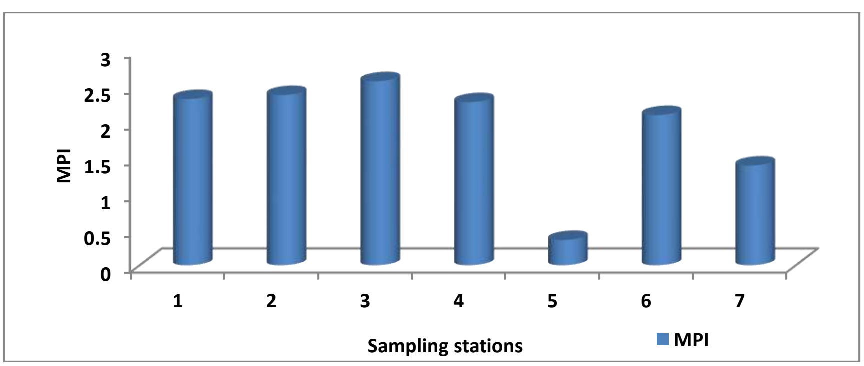

Fig. 3. Variation of metal pollution index of heavy metals in sediments from Achankovil river basin.

3.6 Assessment according to Enrichment factor

Enrichment factors were calculated from the concentration of heavy metal of the study area (Table 7). The normalizing element used in the study was Fe due to low occurrence variability. The low values of Enrichment factors show that the enrichment of sediment by heavy metals was by natural processes. All heavy metals had EF values less than one showed no enrichment. Therefore, the slight heavy metal pollution of the study area was not likely to originate from anthropogenic activities.

3.7 Ecological evaluation of Heavy Metals

In the present study, RI values are greater than 50 and less than 150 indicates that all stations are in slight ecological risk as shown in Table 8.

3.8 Correlation coefficient

The inter elemental association has been evaluated by a Pearson correlation coefficient(r) and the results are represented in Table 9.

Pearson's correlation coefficient matrix among the selected heavy metals is presented in Table 9. Significant correlations between the contaminants of Cd and Cr (r = 0.925), Ni and Cd (r = 0.99), Cr and Ni (r = 0.96), could indicate the same or similar source input. The elemental association may signify that each paired element has an identical source or common sink in the stream sediments [12 & 28]. In most cases; however, there are no significant correlations among most of these heavy metals, suggesting that these metals are not associated with each other. Furthermore, these metals might have different anthropogenic and natural sources in sediments of the area of study.

3.9 Factor analysis

The dimensionality of the metal contamination was reduced from 8 original variables to only 2 factors. These new variables, which accounted for 71% of the total variance, are built by means of a linear combination of the original variables and the eigenvectors. The principal component score plotting (Fig. 4) shows the parameter lines obtained from the factor loadings of the original variables, which represent the contribution of these parameters to the samples. Component loadings of heavy metals of Achankovil river basins were shown in Table 10. The closer the two parameter lines lie together, the stronger is the mutual correlation [39]. Factor 1, accounting for 48%, reflects mainly Cu and factor 2, accounting for 22% indicates Mn and Pb contamination. Cr, Cd and Ni lines indicate a very strong correlation between them. The almost perpendicular relation between Cr with Pb and Mn indicates a very weak correlation between them. There is a strong correlation between Pb and Mn.

Table 7. Enrichment factor of trace metals collected from Achankovil River.

Stations	Cd	Pb	Zn	Cr	Cu	Ni
1	0.003	0.003	0.003	0.003	0.003	0.003
2	0.064	0.064	0.064	0.064	0.064	0
3	0.070	0.070	0.070	0.070	0.070	0.070
4	0.003	0.003	0	0.003	0.003	0.003
5	0.003	0.003	0.003	0.003	0.003	0.003
6	0.007	0.007	0.007	0.007	0.007	0.007
7	0.064	0.064	0.0640	0.064	0.064	0.064

Table 8. Risk indices for trace metals collected from Achankovil River.

Sampling stations	E_f values						RI
	Cu	Cd	Pb	Zn	Cr	Ni	
Station 1	0.80	99.0	1.93	0.65	0.48	102.87	106.75
Station 2	0.53	89.0	2.21	0.32	0.40	92.47	95.95
Station 3	0.58	110.0	2.56	1.02	0.52	114.69	119.39
Station 4	0.03	98.0	2.13	0.23	0.41	100.82	103.64
Station 5	6.09	80.0	0.98	1.01	0.33	88.43	96.86
Station 6	3.84	86.0	6.34	0.56	0.35	97.10	108.20
Station 7	7.69	52.0	2.53	0.76	0.27	63.27	74.54

Table 9. Correlation matrix between trace metals in sediment samples from Achankovil River.

Heavy metals	Cu	Cd	Pb	Zn	Cr	Ni
Cd	1					
Pb	-0.02	1				
Zn	-0.08	-0.20	1			
Cr	0.92	-0.11	0.03	1		
Cu	-0.88	0.05	0.47	-0.85	1	
Ni	0.99	-0.03	0	0.96	-0.86	1

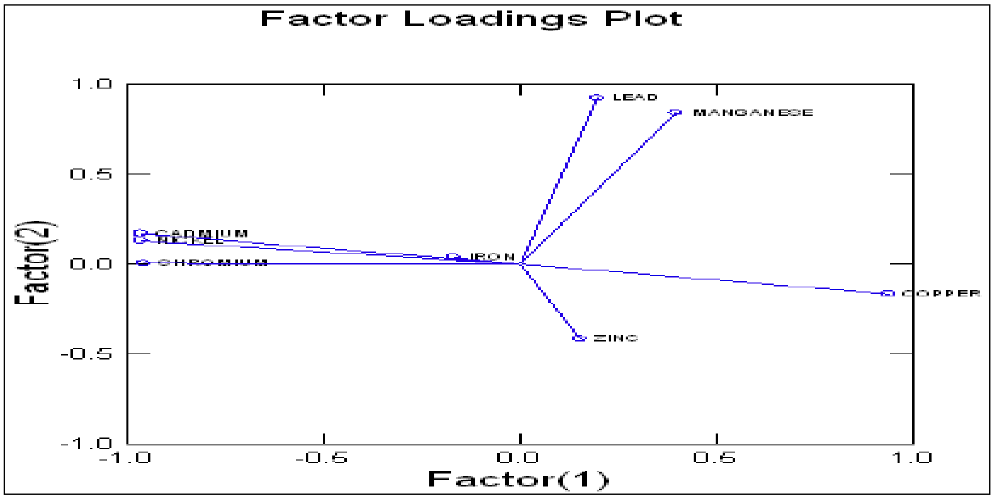

Fig. 4. Principal component factor loading plot of first and second variance.

Table 10. Component loadings of heavy metals of Achankovil River.

Component Loadings		
Heavy metals	1	2
Cadmium	-0.96	0.17
Manganese	0.39	0.84
Lead	0.19	0.92
Zinc	0.15	-0.41
Chromium	-0.95	0.00
Copper	0.93	-0.16
Iron	-0.16	0.03
Nickel	-0.96	0.12

4. Conclusion

Geoaccumulation index, Contamination factor and degree of contamination, Metal pollution index, Enrichment factor and Multivariate statistical analysis were successfully applied for the assessment of heavy metal contamination of Achenkovil river sediments. All stations in the present study recorded low contamination factor for Cr and Ni. Most of the stations showed MPI values > 2 confirming there are considerable heavy metal contamination. In the present study, reported RI values are < 50 and > 150 indicates that all stations are in slight ecological risk. The low values of Enrichment Factors show that the enrichment of sediment by heavy metals is by natural processes. From the correlation studies, it was revealed that there are no significant correlations among most of these heavy metals, suggesting that these metals are not associated with each other. Furthermore, these metals might have different anthropogenic and natural sources in sediments of the area of study. From the principal component factor loading plot, it was found that there is a strong correlation between Cr, Cd and Ni.

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